

Physics With CMS – Potential And Challenges

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Abstract. The CMS muon system is an important subdetector to trigger on and select rare interesting physics events from the large background at the LHC, and to allow kinematic muon reconstruction based on precise momentum measurements. Three detection technologies, all within the magnetized return yoke, identify muons and determine their charge and momentum. The overview outlines the requirements for the muon system, shows their implementation and summarizes the detector performance.

Keywords: LHC experiment, CMS, Muon system, Drift tubes.

PACS:

THE CMS ENVIRONMENT

The Compact Muon Solenoid (CMS) is one of the two multipurpose experiments presently under construction at the Large Hadron Collider (LHC) at CERN. The detector is designed to operate under unprecedented conditions, recording 14TeV center of mass proton-proton collisions. To reach a design luminosity of $10^{34} \text{ cm}^{-2} \text{ s}^{-1}$, a high interaction rate of 40 MHz and high proton bunch densities are envisaged. The latter, along with the proton substructure, yield multiple interactions per bunch crossing and cause many underlying low momentum tracks from the proton fragmentation.

A clear signature based on a few high transverse momentum tracks allows to distinguish interesting physics events from background. A muon trigger and muon momentum determination are mandatory prerequisites to correctly take this decision every 25 ns. The CMS muon system has to provide [1]:

- Muon identification.
- Charge assignment with 99% efficiency up to 7 TeV muon momentum.
- The muon trigger has to select single and multiple muons with a well determined momentum ranging from a few GeV to the TeV scale, and to provide an unambiguous bunch-crossing (BX) assignment.
- Kinematic event reconstruction requires a precise transverse momentum measurement with a η -independent resolution of $dp_T/p_T = 1\text{-}1.5\%$ at $p_T = 10\text{GeV}$ and $dp_T/p_T = 6\text{-}17\%$ at $p_T = 1\text{TeV}$.

THE CMS MUON SYSTEM

The CMS muon system is interleaved with iron constituting the return yoke for the CMS solenoid providing 4T magnetic field for the inner detectors. The detector resolution is limited by multiple scattering to ~ 100 micron per station. The CMS muon system exploits three detection technologies (see Fig. 1) – the barrel region, which instruments pseudorapidities of $|\eta| < 0.8$, uses drift tube (DT) detectors since here the magnetic field is mainly contained in the iron yoke interleaving the chambers. Both forward regions ranging between $1.0 < |\eta| < 2.4$ utilize cathode strip chambers (CSC) which are more suited to cope with the higher and more inhomogeneous magnetic field and the higher particle rates as compared to the barrel. Complementary resistive plate chambers (RPC) are used in both regions to provide a fast response for the muon trigger and redundancy. Special trigger hardware will combine potential track segments seen with different detectors in the barrel and forward regions.

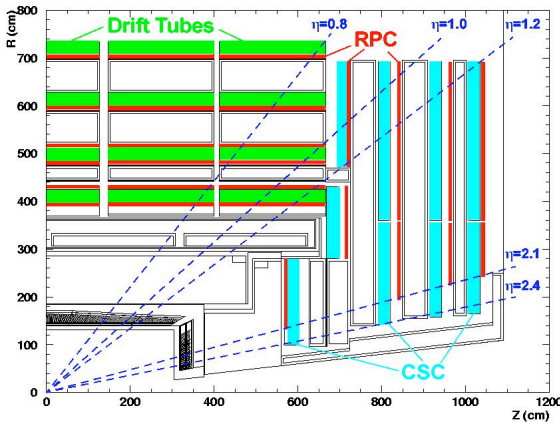


FIGURE 1. A quadrant of the CMS muon system with four drift tube stations and six stations of resistive plate chambers in the muon barrel, along with four stations of cathode strip and resistive plate detectors in the forward regions. The pseudorapidity ranges for the barrel and forward regions are indicated.

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Drift Tube Chambers For The Muon Barrel

High resolution tracking and momentum measurement in the muon barrel is provided by 250 drift tube chambers organized in five mechanically independent wheels. A muon originating at the nominal interaction point traverses four stations, each of which measures 3D coordinates in 2×4 layers of drift cells in the bending plane and 4 layers perpendicular to it. The individual drift cells are rectangular with a cross section of 13×42 mm and a length of 2-3m. They are staggered by half a cell between layers to resolve the left/right ambiguity intrinsic to the technology. With this cell size and a gas mixture of 85% argon and 15% CO_2 , the maximum drift time is 380 ns corresponding to about 16 bunch crossings. The single cell resolution of $250 \mu\text{m}$ is determined by the drift behavior, leading to the chamber resolution (12 layers) of $\sim 100 \mu\text{m}$.

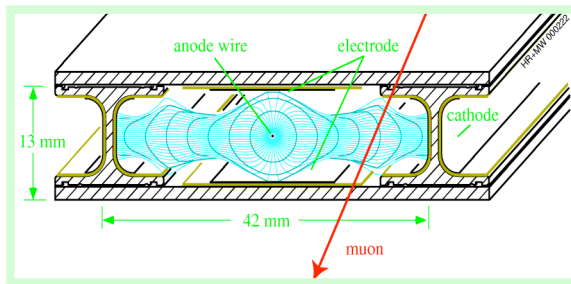


FIGURE 2. An individual drift cell (in total there are about half a million for the whole barrel system) is of rectangular shape. Along the shorter cell dimension the track curvature provides a measure of the muon momentum. Besides the central anode wire and cathodes (left and right of the cell), field shaping electrodes below and above the wire help to form a uniform drift field.

Cathode Strip Chambers For The Forward Regions

The forward muon detectors experience up to two orders of magnitude higher particle flux (max. $1\text{kHz}/\text{cm}^2$) as compared to the barrel detectors (max. $10\text{Hz}/\text{cm}^2$) due to the bending properties of the solenoidal magnetic field, and particle boosts in proton-proton collisions. Cathode strip chambers, a kind of multi-wire proportional chamber, can cope with such high rates while providing a fast readout and insensitivity to magnetic fields. Segmented strips run in radial direction to measure the bending of the particle track with $\sim 100\mu\text{m}$ resolution. The precision is given by the center of gravity method and is good even for wide strips. Perpendicular to the strips are anode wires which measure the fast signal from the drifting primary electrons (time resolution 4-5ns) to determine the radial position and the bunch crossing assignment.

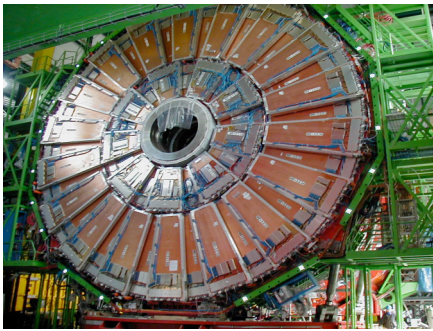


FIGURE 3. The forward muon cathode strip detectors have a trapezoidal shape with six sensitive layers each. 450 such chambers are arranged to form two end-caps of four muon stations each. Overlap between the chambers ensures full geometrical coverage up to pseudorapidities of $|\eta|=2.4$. The chambers operate with a gas mixture of 30% Ar, 50% CO_2 and 10% CF_4 and high voltages of 3000-4100V.

Resistive Plate Chambers

One of the tasks of the muon system is to provide a first level trigger to the CMS global event selection. Although trigger information is provided by CSCs and DTs, a dedicated system of resistive plate chambers with <3 ns time resolution cover a 6000m^2 area in the barrel and forward regions. They also provide redundancy for tracking in the bending plane. For better efficiency, each tracking station combines two 1 mm gaps with a central readout strip. The detectors are filled with a gas mixture of 96.7% TFE, 3% Iso-Butane and 0.3% SF_6 , and are operated at 9.5 kV voltage.

Alignment

Several mechanically independent units – two end-caps and five barrel wheels – make up the muon system and will move when the magnet is turned on. A laser-based alignment system monitors the positions of a subset of individual detectors with 0.1 mm precision. The CMS alignment system has three building blocks: internal tracker alignment, internal muon alignment, and a link between both subdetectors. The latter is important in CMS since the ultimate momentum resolution can only be achieved by a combination of both. For low momentum particles, the momentum resolution of the muon system is limited by multiple scattering in the iron, while for momenta >300 GeV the muon momentum resolution exceeds that of the tracker.

REFERENCES

1. CMS Technical Design Report: The Muon Project, *CERN/LHCC 97-32, CMS TDR3, 15.December 1997.*